

CLAIMS

What is claimed is:

1. A connection protection mechanism for an optical cross-connect switch, the connection protection mechanism comprising:
- the optical cross-connect switch to couple to client equipment, the optical cross-connect switch to bi-directionally transport optical signals with the client equipment, the optical cross-connect switch including one or more working ports to couple to the client equipment, each of the one or more working ports to couple to the client equipment using a pair of working links, and
- a protection port to couple to the client equipment using a pair of protection links;
- and
- a signaling channel to transport a connection failure signal indicating if one working port of the one or more working ports has a connection failure in its working link or the one working port coupling to the client equipment.
2. The connection protection mechanism of claim 1 wherein,
- if the one working port of the one or more working ports has the connection failure, the optical cross-connect switch to switch the coupling to the client

6 equipment from the one working port to the protection
7 port.

1 3. The connection protection mechanism of claim 1
2 wherein,
3 the optical cross-connect switch is without an
4 optical-electrical-optical converter (O/E/O) but has a
5 sensor to detect the connection failure.

1 4. The connection protection mechanism of claim 1
2 wherein,
3 the client equipment includes one or more of the set
4 of wavelength division multiplexed (WDM) line terminals,
5 SONET add/drop multiplexers, internet protocol (IP)
6 routers, additional optical cross-connect switches and
7 Asynchronous Transfer Mode (ATM) switches.

1 5. The connection protection mechanism of claim 1
2 wherein,
3 the optical cross-connect switch further includes
4 at least one network port to couple to a
5 network to bi-directionally transport optical
6 signals with the network.

1 6. The connection protection mechanism of claim 5
2 wherein,
3 the optical cross-connect switch further includes
4 a first optical switch fabric of optical
5 switches to connect at least one pair of optical

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6      signals between the network equipment and the client
7      equipment.
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1 7. The connection protection mechanism of claim 1
2 wherein,
3 the optical cross-connect switch further includes a
4 first optical switch fabric, and
5 if the one working port of the one or more working
6 ports has the connection failure, the first optical
7 switch fabric to switch the coupling to the client
8 equipment through the one working port to the protection
9 port.

1 8. The connection protection mechanism of claim 1
2 wherein,
3 the signaling channel is an out-of-band signaling
4 channel.

1 9. The connection protection mechanism of claim 8
2 wherein,
3 the out-of-band signaling channel is a communication
4 channel over a network.

1 10. The connection protection mechanism of claim 9
2 wherein,
3 the optical cross-connect switch further includes
4 a network management controller to couple to a
5 network and the one or more working ports and the
6 protection port, the network management controller

1 14. The connection protection mechanism of claim 8
2 wherein,
3 the in-band signaling channel is a dedicated
4 signaling link in parallel with each of the pair of
5 working links.

1 15. The connection protection mechanism of claim 6
2 wherein,
3 the optical cross-connect switch further includes
4 a second optical switch fabric of optical
5 switches to provide a redundant optical switch
6 fabric in case of a failure in the first optical
7 switch fabric,
8 and
9 wherein if the one working port of the one or more
10 working ports has the connection failure, the second
11 optical switch fabric to switch the coupling to the
12 client equipment through the one working port to the
13 protection port.

1 16. The connection protection mechanism of claim 1
2 wherein,
3 the optical cross-connect switch further includes
4 a second protection port to couple to the
5 client equipment using a second pair of protection
6 links
7 and,
8 wherein if the one working port of the one or more
9 working ports has the connection failure, the optical
10 cross-connect switch to switch the coupling to the client
11 equipment from the one working port to the second
12 protection port.

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1 17. The connection protection mechanism of claim 6
2 wherein,
3 the optical switches of the optical switch fabric
4 are micro-machined mirrors to direct optical signals
5 between the client and the network.

1 18. A method for protecting connections between an
2 optical cross-connect switch and a client, the method
3 comprising:

4 detecting a connection failure on a working
5 link of a pair of working links between the optical
6 cross-connect switch and the client;
7 signaling the optical cross-connect switch or
8 the client of the connection failure in response to
9 detecting the connection failure; and
10 switching to a pair of protection links between
11 the optical cross-connect switch and the client from the
12 pair of working links having the connection failure.

1 19. The method of claim 18 wherein,
2 the optical cross-connect switch is without an
3 optical-electrical-optical converter (O/E/O) but has a
4 sensor to detect the connection failure.

1 20. The method of claim 18 wherein,
2 the client includes one or more of the set of
3 wavelength division multiplexed (WDM) line terminals,
4 SONET add/drop multiplexers, internet protocol (IP)

5 routers, additional optical cross-connect switches and
6 Asynchronous Transfer Mode (ATM) switches.

1 21. The method of claim 18 further comprising:

2 providing a signaling channel between the

3 optical cross-connect switch and the client; and

4 wherein the signaling includes

5 transmitting a connection failure signal over

6 the signaling channel to the optical cross-connect switch

7 or the client in response to detecting the connection

8 failure.

1 22. The method of claim 21 wherein,
2 the signaling channel is an out-of-band signaling
3 channel.

1 23. The method of claim 18 further comprising:
2 cross-connecting optical signals between the client
3 and a communication network using micro-machined mirrors.

1 24. The method of claim 18 wherein,
2 the connection failure is detected by the optical
3 cross-connect switch in the working link from the client
4 to the optical cross-connect switch, and the optical
5 cross-connect switch signals the connection failure to
6 the client by
7 disabling optical signal propagation from the
8 optical cross-connect switch to the client over the

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1 27. The method of claim 18 wherein,
2 the connection failure is detected by the client in
3 the working link from the optical cross-connect switch to
4 the client, and the client signals the connection failure
5 to the optical cross-connect switch by
6 disabling optical signal propagation from the client
7 to the optical cross-connect switch over the working link
8 from the client to the optical cross-connect switch
9 without the connection failure of the pair of working
10 links with the connection failure.

1 28. The method of claim 18 wherein,
2 the connection failure is detected by the client in
3 the working link from the optical cross-connect switch to
4 the client, and the client signals the connection failure
5 to the optical cross-connect switch by
6 transmitting an optical signal having a pattern over
7 the working link from the client to the optical cross-
8 connect switch without the connection failure, the
9 pattern indicating the connection failure in the working
10 link from the optical cross-connect switch to the client.

1 29. A connection protection interface for an optical
2 cross-connect switch, the connection protection interface
3 comprising:
4 one or more I/O port cards in the optical cross-
5 connect switch, each of the one or more I/O port cards to
6 couple to a client equipment using working optical links;
7 and
8 M protection port cards for every N I/O port cards
9 of the one or more I/O port cards, the M protection port
10 cards to couple to the client equipment using protection
11 optical links.

1 30. The connection protection interface of claim 29
2 wherein,
3 the protection port cards to bi-directionally
4 transport optical signals with the client equipment over
5 the protection optical links in the event of a connection

6 failure in a working link in one of the one or more I/O
7 port cards.

1 31. The connection protection interface of claim 29
2 wherein,
3 each of the working optical links is a pair of
4 optical fiber and each of the protection optical links is
5 a pair of optical fibers.

1 32. The connection protection interface of claim 29
2 wherein,
3 each of the working optical links is a single
4 optical fiber and each of the protection optical links is
5 a single optical fiber.

1 33. The connection protection interface of claim 29
2 wherein,
3 M is greater than or equal to one and N is greater
4 than or equal to one.

1 34. The connection protection interface of claim 29
2 wherein,
3 each of the one or more I/O port cards of the
4 optical cross-connect switch is without an optical-
5 electrical optical converter (O/E/O) but each has a
6 sensor to detect the connection failure between the
7 client equipment and the optical cross-connect switch.

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1 35. The connection protection interface of claim 29
2 wherein,
3 the client equipment includes one or more of the set
4 of wavelength division multiplexed (WDM) line terminals,
5 SONET add/drop multiplexers, internet protocol (IP)
6 routers, additional optical cross-connect switches and
7 Asynchronous Transfer Mode (ATM) switches.

1 36. The connection protection interface of claim 29
2 wherein,
3 the one or more I/O port cards to communicate with
4 the client equipment are client port cards.

1 37. The connection protection interface of claim 29
2 wherein,
3 at least one I/O port card to communicate with a
4 network and is a network port card.

1 38. The connection protection interface of claim 29
2 wherein,
3 each of the one or more I/O port cards further has a
4 dedicated signal line to couple to a respective I/O port
5 card of the client equipment, the dedicated signal line
6 to transmit and receive connection failure signals
7 regarding the connection between the optical cross-
8 connect switch and the client equipment.

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1 39. The connection protection interface of claim 29
2 further comprising:

3 an out of band signaling channel to transmit a
4 connection failure signal in response to the sensor
5 detecting a connection failure in a working link from the
6 client equipment to the optical cross-connect switch.

1 40. The connection protection interface of claim 39
2 wherein,

3 the connection failure signal indicates the
4 connection failure and which of the one or more I/O
5 port cards has the connection failure.

1 41. The connection protection interface of claim 29
2 wherein,

3 the connection failure is detected by the optical
4 cross-connect switch in a working link from the client
5 equipment to the optical cross-connect switch, and the
6 optical cross-connect switch signals the connection
7 failure to the client equipment by

8 disabling optical signal propagation from the
9 optical cross-connect switch to the client equipment over
10 the working link without the connection failure of the
11 one I/O port card of the one or more I/O port cards with
12 the connection failure.

1 42. The connection protection interface of claim 29
2 wherein,

3 the connection failure is detected by the optical
4 cross-connect switch in a working link from the client
5 equipment to the optical cross-connect switch, and the
6 optical cross-connect switch signals the connection
7 failure to the client equipment by

8 transmitting an optical signal having a pattern over
9 the working link without the connection failure of the
10 one I/O port card of the one or more I/O port cards with
11 the connection failure, the optical signal having the
12 pattern indicating the connection failure in the working
13 link from the client to the optical cross-connect switch.

1 43. The connection protection interface of claim 42
2 wherein,

3 the pattern of the optical signal indicates the
4 connection failure and which of the one or more I/O port
5 cards has the connection failure.

1 44. A protected connection between an optical cross-
2 connect switch and a client equipment in a communication
3 network system, the protected connection comprising:

4 one or more pairs of optical links coupled between
5 the optical cross-connect switch and the client equipment
6 as working links over which optical signals ordinarily
7 propagate without a connection failure; and

8 at least one pair of optical links coupled between
9 the optical cross-connect switch and the client equipment
10 as protection links over which optical signals can

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11 atypically propagate in the event of a connection
12 failure.
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1 45. The protected connection of claim 44 wherein,
2 the optical cross-connect switch includes,
3 one or more input/output (I/O) ports coupled to
4 the one or more pairs of optical links as the
5 working links to connect and bi-directionally
6 transport optical signals with the client equipment,
7 and

8 at least one protection port to couple to the
9 at least one pair of optical links as the protection
10 links to connect with the client equipment and
11 atypically bi-directionally transport optical
12 signals with the client equipment in the event of a
13 connection failure in the working links of the one
14 or more pairs of optical links;
15 and

16 the client equipment includes,

17 one or more I/O ports coupled to the one or
18 more pairs of optical links as the working links to
19 connect and bi-directionally transport optical
20 signals with the optical cross-connect switch, each
21 of the one or more I/O ports having a sensor to
22 detect a connection failure between the client
23 equipment and the optical cross-connect switch, and

24 at least one protection port to couple to the
25 at least one pair of optical links as the protection

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26 links to connect with the optical cross-connect
27 switch and atypically bi-directionally transport
28 optical signals with the optical cross-connect
29 switch in the event of a connection failure in the
30 working links of the one or more pairs of optical
31 links.

1 46. The protected connection of claim 45 wherein,
2 the one or more I/O ports of the optical cross-
3 connect switch are without an optical-electrical-optical
4 converter (O/E/O) but each has a sensor to detect a
5 connection failure between the client equipment and the
6 optical cross-connect switch.

1 47. The protected connection of claim 44 wherein,
2 the client equipment includes one or more of the set
3 of wavelength division multiplexed (WDM) line terminals,
4 SONET add/drop multiplexers, internet protocol (IP)
5 routers, additional optical cross-connect switches and
6 Asynchronous Transfer Mode (ATM) switches.

1 48. The protected connection of claim 44 further
2 comprising:
3 an out-of-band signaling channel between the client
4 equipment and the optical cross-connect switch, the out-
5 of-band signaling channel to transmit a connection
6 failure signal in response to detection of a connection
7 failure in the working links between the client equipment
8 and the optical cross-connect switch.

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4 are one or more dedicated signal lines coupled between
5 the respective one or more I/O ports of the client
6 equipment and the optical cross-connect switch, the one
7 or more dedicated signal lines to transmit and receive
8 connection failure signals regarding the connection
9 between the optical cross-connect switch and the client
10 equipment.

1 54. The protected connection of claim 51 wherein,
2 the one or more in-band signaling channels between
3 the client equipment and the optical cross-connect switch
4 are
5 the optical links without the connection failure of
6 the one or more pairs of optical links of the working
7 links having the connection failure, the optical links
8 without the connection failure to propagate connection
9 failure signals regarding the connection between the
10 optical cross-connect switch and the client equipment.

1 55. The protected connection of claim 51 wherein,
2 the connection failure is detected by an I/O port of
3 the optical cross-connect switch in an optical link of a
4 pair of optical links and the optical cross-connect
5 switch signals the connection failure to the client
6 equipment by

7 disabling optical signal transport from the optical
8 cross-connect switch to the client equipment over another
9 optical link without the connection failure of the pair
10 of optical links.

$\frac{d}{dt} \left(\frac{\partial L}{\partial v^i} \right) = \frac{\partial L}{\partial x^i}$, $i=1,2,\dots,n$

1 56. The protected connection of claim 51 wherein,
2 the connection failure is detected by an I/O port of
3 the optical cross-connect switch in an optical link of a
4 pair of optical links and the optical cross-connect
5 switch signals the connection failure to the client
6 equipment by
7 transmitting an optical signal having a pattern over
8 another optical link without the connection failure of
9 the pair of optical links, the optical signal having the
10 pattern indicating the connection failure in the optical
11 link.

1 57. The protected connection of claim 51 wherein,
2 the connection failure is detected by an I/O port of
3 the client equipment in an optical link of a pair of
4 optical links and the client equipment signals the
5 connection failure to the optical cross-connect switch by
6 disabling optical signal transport from the client
7 equipment to the optical cross-connect switch over
8 another optical link without the connection failure of
9 the pair of optical links.

1 58. The protected connection of claim 51 wherein,
2 the connection failure is detected by an I/O port of
3 the client equipment in an optical link of a pair of
4 optical links and the client equipment signals the
5 connection failure to the optical cross-connect switch by

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6 transmitting an optical signal having a pattern over
7 another optical link without the connection failure of
8 the pair of optical links, the optical signal having the
9 pattern indicating the connection failure in the optical
10 link.

1 59. A connection protection mechanism for optical
2 network equipment, the connection protection mechanism
3 comprising:

4 the optical network equipment to couple to client
5 equipment, the optical network equipment to bi-
6 directionally transport optical signals with the client
7 equipment, the optical network equipment including
8 one or more working ports to couple to the
9 client equipment, each of the one or more working
10 ports to couple to the client equipment using a pair
11 of working links, and

12 a protection port to couple to the client
13 equipment using a pair of protection links;
14 and

15 a signaling channel to transmit and receive a
16 connection failure signal indicating if one working port
17 of the one or more working ports has a connection failure
18 in a working link or a working port coupling to the
19 client equipment.

1 60. The connection protection mechanism of claim 59
2 wherein,

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